Transportation Research Part B 67 (2014) 320–343

Contents lists available at ScienceDirect

Transportation Research Part B

journal homepage: www.elsevier.com/locate/trb

Airline route structure competition and network policy

Hugo E. Silva *, Erik T. Verhoef, Vincent A.C. van den Berg

Department of Spatial Economics, VU University Amsterdam, De Boelelaan 1105, 1081 HV Amsterdam, The Netherlands
Tinbergen Institute, Gustav Mahlerplein 117, 1082 MS Amsterdam, The Netherlands

ARTICLE INFO

Article history:
Received 8 October 2013
Received in revised form 20 May 2014
Accepted 21 May 2014

Keywords:
Route structure competition
Aviation policy
Hub-and-spoke networks
Fully-connected networks

ABSTRACT

We analyze the behavior of airlines in terms of route structure choice using a differentiated duopoly model that accounts for congestion externalities, passenger benefits from increased frequency, passenger connecting costs and airline endogenous hub location. We also examine the route structure configuration that maximizes welfare and whether it can arise as an equilibrium when a regulator implements optimal airport pricing, but does not regulate directly the route structure choice. We find that this is not always the case and that, therefore, an instrument directly aimed at regulating route structure choice may be needed to maximize welfare, in addition to per-passenger and per-flight tolls designed to correct output inefficiencies. This holds true when the regulator is constrained to set non-negative tolls, but also for unconstrained tolling. Finally, we also study the relative efficiency of airport pricing when the optimal route structure configuration cannot be decentralized by tolling.

1. Introduction

Following the deregulation of the airline industry, several changes in aviation markets were observed (see Morrison and Winston (1995) for an overview of the changes in the US industry, and Burghouwt and Hakfoort (2001) for Europe). In addition to changes in fares, the most notorious change was in the way markets were served: the adoption of hub-and-spoke route structures by carriers became dominant. Also since the deregulation of the markets, the costs caused by congestion at airports have grown significantly and managing the increasing congestion has become one the main concerns of governments in countries with a large aviation market. For example, Ball et al. (2010) estimate that the cost of US air transportation delay in 2007 was $16.7 billions to passengers, $8.3 billions to air carriers and that it reduced the 2007 GDP by $4 billion. Not surprisingly, optimal airport pricing has gained increased attention as a measure aimed at reducing congestion costs.

The objective of this paper is to analyze optimal airport pricing in a network setting and in the presence of congestion externalities, where carriers with market power have the route structure choice as a strategic instrument. It is known from earlier literature, which abstracts away from endogenous route structure, that oligopolistic carriers partially internalize congestion and exert market power (e.g., Brueckner, 2002; Pels and Verhoef, 2004). This means that two inefficiencies need to be corrected: the deadweight loss from market-power markups (e.g. with subsidies) and the excessive number of flights that are scheduled (e.g. with slot constraints or congestion pricing).[1] In this paper, we study whether and how the inclusion of route structure choice by carriers changes these conclusions. Specifically, do regulators need an additional instrument, on top of the ones described above, to induce the socially desirable outcome? We carry out the analysis in what we believe is

* Corresponding author. Tel.: +31 20 59 86106.
E-mail addresses: h.silvamontalva@vu.nl (H.E. Silva), e.t.verhoef@vu.nl (E.T. Verhoef), vberg@feweb.vu.nl (V.A.C. van den Berg).

[1] See Zhang and Czerny (2012) for an up-to-date review on airport pricing.

http://dx.doi.org/10.1016/j.trb.2014.05.012
0191-2615/

the simplest possible setting that allows us to account for strategic interactions in route structure choice, endogenous hub locations, market power exertion by airlines, congestion externalities at airports, and passenger frequency benefits and transfer costs.

The conditions that give rise to hub-and-spoke route structures as an equilibrium of unregulated competition have often been explained with three arguments: economies of density, frequency effects and strategic advantages. The first refers to that average cost in a direct route may decrease with the number of passengers, and the second, the frequency effect, to the fact that there are benefits for passengers of increased frequencies, e.g. reductions in schedule delay costs (the difference between desired and actual departure/arrival time). Both may be better exploited under hub-and-spoke structures. In a monopoly framework, Hendricks et al. (1995) show that economies of density alone can induce an airline to adopt a hub-and-spoke route structure; Brueckner (2004) shows how frequency effects favor the adoption of hub-and-spoke. The third argument, strategic advantages, reflects that adopting hub-and-spoke route structures may bring, in oligopolistic competition, further advantages because of the effect it has on competitors. For instance, Oum et al. (1995) show that using a hub-and-spoke structure may allow the carrier to be more aggressive in output market competition. Employing hub-and-spoke can deter entry in hub markets if the complementarities among hub markets are large, or the number of complementary hub markets is large (Hendricks et al., 1997). Finally, it may prevent competition in local markets between two hub carriers because invading the competitor's local market may reduce own profit in all connecting markets due to a more aggressive competition in the trans-hub market (Zhang, 1996). Recent theoretical contributions to this topic include Hendricks et al. (1999), Alderighi et al. (2005), Barla and Constantatos (2005), and Flores-Fillol (2009, 2010).[2]

The above studies, however, ignore the endogenous nature of the hub location, do not study the socially optimal route structure, and most of them also ignore congestion effects. This paper contributes to the literature by including all these together. For example, we find that airlines choosing hub-and-spoke structures using different cities as their hub may be the unique equilibrium when airports, markets and airlines are symmetric. The consideration of asymmetric hub-and-spoke networks, commonly observed in real markets, is an important contribution of this paper. In addition, we show that the result that a monopolistic airline is biased towards hub-and-spoke configurations (Brueckner, 2004) does not necessarily carry over to competing airlines under our assumptions. We find that airlines adopting fully connected route structures can be the unique equilibrium when using hub-and-spoke structures is socially optimal.

The literature on pricing and regulation in aviation markets has mostly focused on either a single origin destination pair, hence ignoring network effects, or in networks with fixed route structures, hence ignoring its endogenous nature and its effect on optimal policy. Brueckner (2004) compares the optimal route structure in a three-node network with the one adopted by an unregulated monopoly, but does not study pricing policies. Flores-Fillol (2009) extends the analysis to a duopoly of airlines without analyzing the optimal route structure. Brueckner (2005) and Flores-Fillol (2010) study the optimal pricing policy in a duopoly setting with an exogenous route structure. Our contribution to the policy analysis is to identify the rationale for the tolls, when route structure is endogenous, and to extend the optimal pricing and regulation analysis by elaborating on the policy instruments that can decentralize the socially efficient outcome in terms of output and network configuration.

A main result of our analysis is that a regulatory instrument directly targeted on route structure choice may be needed to maximize welfare, in addition to tolls designed to induce the efficient outputs, given the networks chosen. We find that social welfare can be increased by using an additional policy instrument when the regulator is restrained from subsidizing airlines (needed to eliminate deadweight losses), but also when it does not face such constraint on tolling. Specifically, the first-best optimal route structures and output levels cannot always be decentralized by just using an airline- and market-specific per-passenger toll (to correct for market power), together with an airline- and link-specific per-flight toll (to correct for congestion), designed to induce the efficient output for the optimal route structure. Thus, the equilibrium with those tolls is not always efficient, even when the regulator can perfectly discriminate airlines and has no pricing constraints. This is because these tolls, despite that they provide the incentives to set the output efficiently, cannot always align the effect of adopting different route structures on the firms' profit with the effect on social welfare of those different configurations. This is especially true when the optimal network configuration is asymmetric and requires one firm to have, in one of the markets, a significantly lower market share and profit than the competitor.

First-best pricing, as just discussed, typically requires a regulator to give per-passenger subsidies to airlines, a policy that is arguably impossible to implement in practice. To address this limitation, we study the case in which the regulator is constrained to charge non-negative tolls. We show that the route structures and output levels that maximize welfare in absence of subsidies to correct for market power exertion cannot always be decentralized through non-negative tolls alone. Thus, also in the absence of subsidization, using an additional regulatory instrument, on top of the tolls designed to correct output inefficiencies, may increase welfare.

Our results may have important policy implications. In some cases an instrument directly aimed at regulating route structure choice is needed for welfare maximization, and in the cases where the pricing instruments are sufficient, the rationale for the charges is not always the same. In some cases they are required only to correct output choices, in other cases the tolls are needed to correct simultaneously output and route structure choices, and finally they can also be needed in order to change the market structure in terms of suppliers present in the network, in addition to correct output and route structure.

[2] For an empirical analysis and review of the size and shape of the networks in the airline industry from a cost perspective, see Jara-Díaz et al. (2013).